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Published in:
Proceedings

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

Laser Doppler scanners for measuring flow over terrain

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January 2011 – EERA workshop on wind conditions, Porto, Portugal

Doppler lidar instruments

ZephIR: continuous wave, WindCube: pulsed

Doppler lidar instruments

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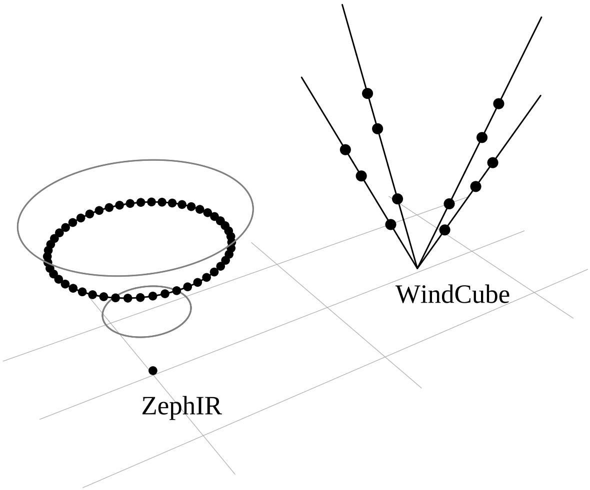
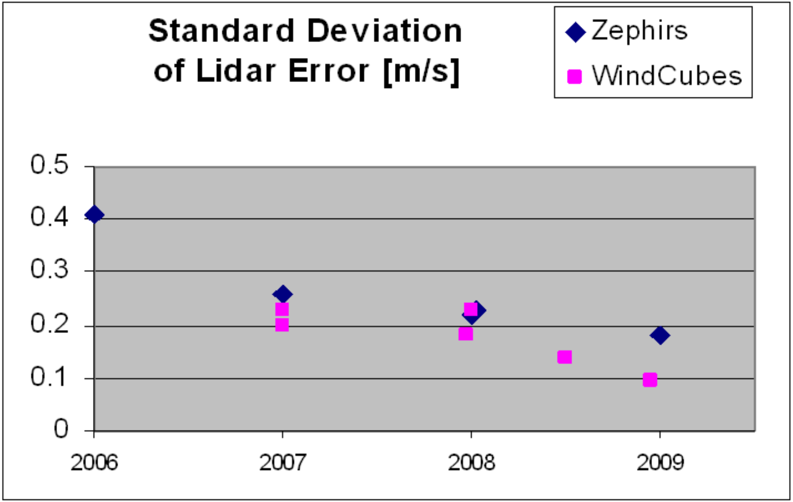


Mean wind speed measurements over flat terrain

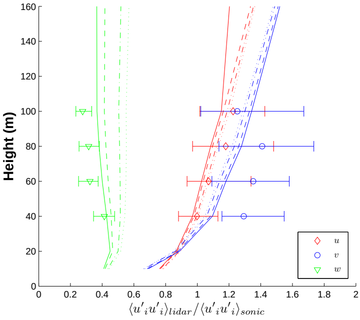
ZephIR and WindCube



(Courtney *et al.* 2008 & 2011)

Turbulence measurements over flat terrain works less well

Systematic error under different atmospheric stability conditions; WindCube: Unstable and stable



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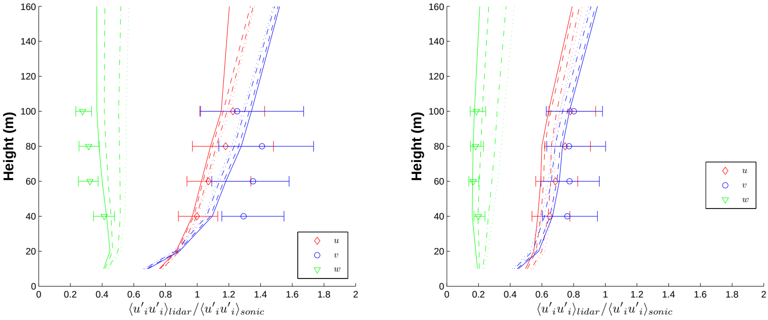
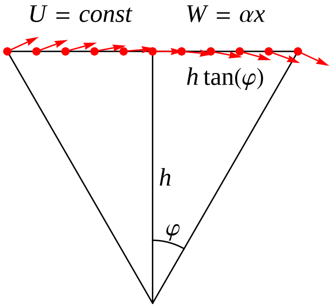


Conical scanning in non-homogeneous flow



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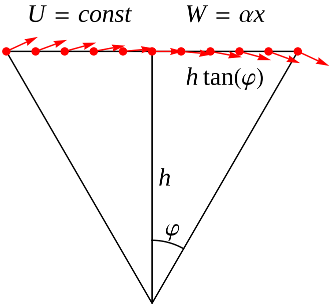

$$\begin{aligned} v_{up} &= (-\sin\varphi, \cos\varphi)\cdot(U, -h\alpha\tan\varphi) \\ &= -U\sin\varphi - h\alpha\sin\varphi \\ &= -(U + h\alpha)\sin\varphi \end{aligned}$$

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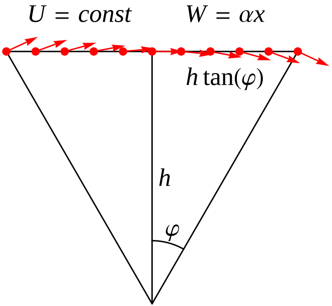

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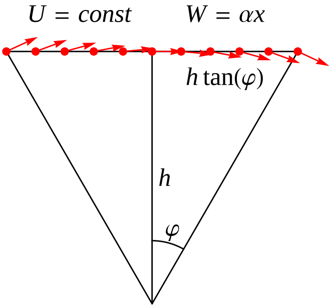

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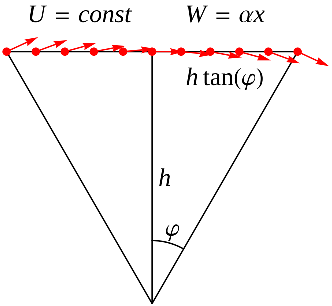

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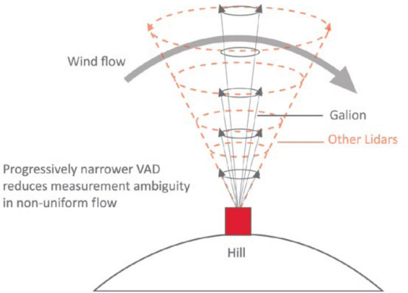
Does not depend on φ!

Smaller opening angle φ

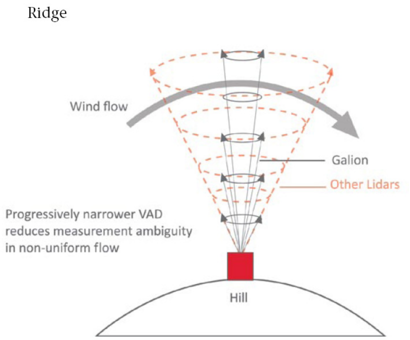
A suggested solution

Ridge



Smaller opening angle φ

A suggested solution



- ↯ Should not work in theory

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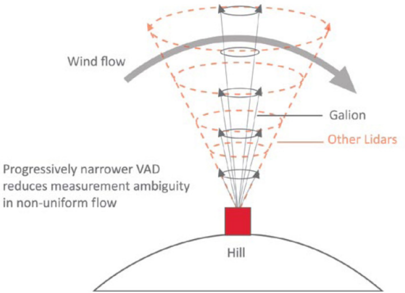
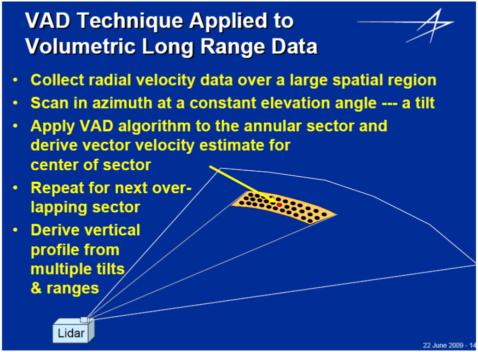


- ↯ Should not work in theory
- ↯ Has not been demonstrated in practice

Mapping wind speed over complex terrain

Lockheed Martin Coherent Technologies and RES



↯Still systematic errors on wind components “perpendicular” to the beam

Other possible solutions

- Use flow models to calculate correction
  1. Bingöl et al 2009 *Met Zeit* (WAsP Engineering)
  2. Mean W measurements: Dellwik *et al*, 2010, *BioGeoSciences*
  3. Natural Power at EWEC 2010 (Ventos)

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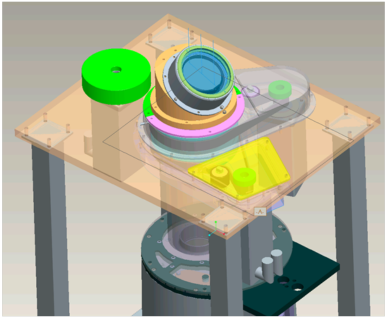
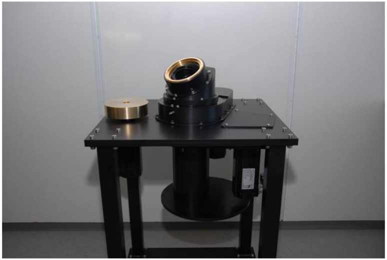
- *Use three lidars!*

Short range wind scanner

Combine three ZephIRs and move the beams fast

Scanning performed with a patented double prism system





Long range wind scanner

Combine three WindCubes and move the beams sedately

Specifications of long-range wind-scanner

WLS70 + Risø DTU/Leosphere scan head

- Range: 1.5 – 5 km, depending on sampling time and aerosols

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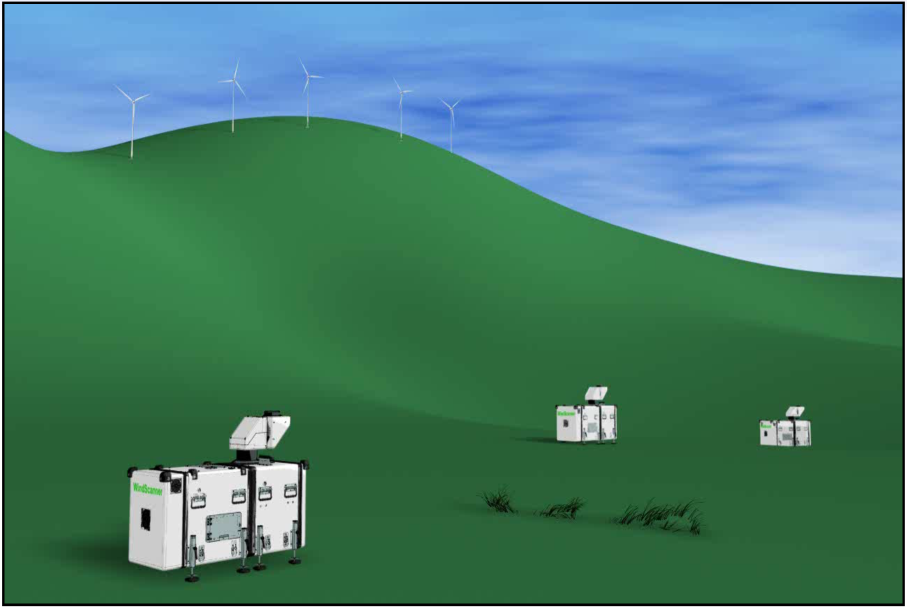
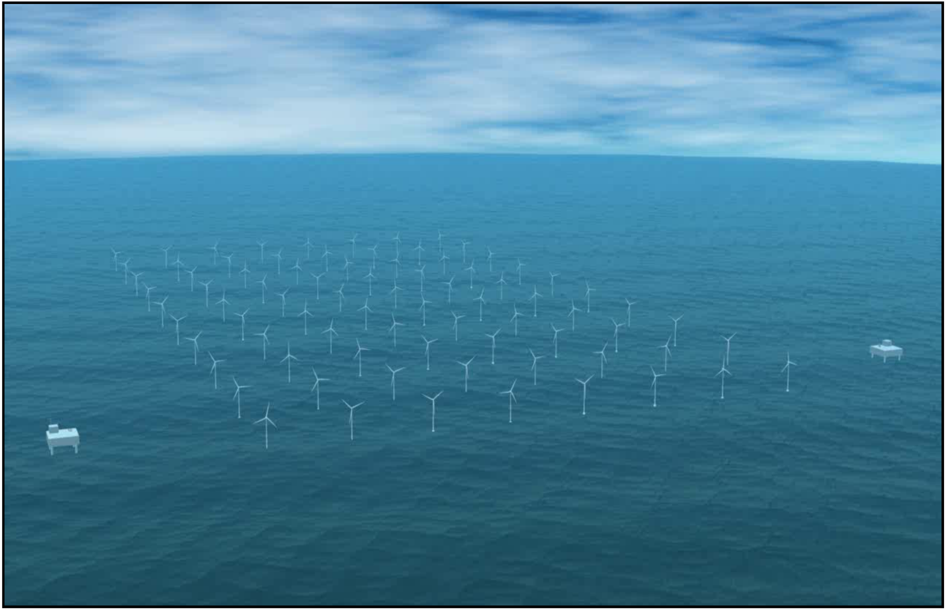
- Resolution: 55 m along beam, 1 – 10 measurements/s
- Scanner: <2 mrad, velocity 50°/s, acceleration 100°/s^2


WindScanner



Conclusion

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- It is necessary to use three lidars for accurate wind measurements over complex terrain
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  - A short range system based on Natural Power's ZephIRs
  - A long range based on Leosphere WindCubes.